Center Innovation Fund: GSFC CIF

ALD Modified Nanostructured Geometries for Rectification and MEMS Thermal Control

Completed Technology Project (2014 - 2015)

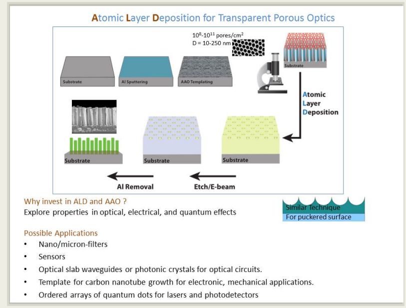
Project Introduction

Through the introduction of paired precursor gases, thin films can be deposited on a myriad of substrates ranging from glass, polymers, aerogels, and metals – from flat surfaces to those with significant topography. This technology benefits GSFC and NASA in providing a novel method to facilitate the production, optimization and protection of valuable spaceflight hardware. It is the deposition of surfaces with high aspect ratio geometries that is the basis of this project. We propose to investigate the use of ALD to fill AAO, anodic aluminum oxide, nanoscale pores with candidate metal/insulator materials to create a viable surface for energy harvesting, energy storage, filtration and nanoscale thermal protection. The judicious selection of geometries, materials and thicknesses can create many tiny rectifiers, nanotubes, or nanocones that can operate in parallel to convert high field electromagnetic radiation into current, photovoltaics, or nanoscaled thermal films.

The application of nanotechnology to create a new type of optical/IR detector has been under development for many years. The fabrication of nano antennas to collect visible and Infrared radiation for sensing or power generation has progressed, while the means for rectification of 300- 500 TerraHertz radiation has lagged. The high frequency of the electric field requires operation on a very small spatial scale utilizing processes such as electron tunneling. Metal Insulator Metal (MIM) junctions have shown promise but the extreme control of the thickness and purity of the insulator level has proved a major barrier. The use of Atomic Layer Deposition (ALD) to apply the materials in precise and pure form may enable the use of new approaches that can be more accurate in the form and purity of the deposition. Fabrication of an integrated device will happen via a companion IRAD proposal to be submitted by John Hagopian and his team with co-funding from another source.

The miniaturization of power dense electronic systems, such as microprocessors, multi-chip modules, and laser diode arrays, has driven the development of ultra-compact heat exchangers that employ flow boiling in microscale fluid ducts. Due to space constraints, boiling augmentation techniques for conventional channels cannot be directly incorporated in microchannels. Surface enhancement via nanoporous coatings is a promising technique for improving the key metrics of flow boiling in microchannels: surface superheat required for the onset of nucleate boiling, two-phase heat transfer coefficient, and critical heat flux. These improvements are the result of coating's ability to improve surface wicking characteristics, surface wettability, and nucleation site density. Furthermore, nanoporous coatings have been reported to enhance surface hardness, surface wear resistivity, and corrosion resistivity; each of these benefits improves system lifetime.

The foundation of this proposed work is to utilize a custom built in situ ALD reactor developed by the PI to conformally coat AAO pores with either a



Method to create nanotubes, nanocones using ALD

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conformal film of candidate metals or with thickness that vary across the pore length to produce bow tie or sharp tip type geometries. The reactor itself is a laminar flow tube type reactor where candidate precursor gases are pulsed in from one end of a heated three-foot tube and evacuated from the other end of the tube in vacuum. As mentioned, ALD utilizes discrete pulses of precursor gases to grow films with atomic precision. In the case of alumina films, Al2O3, the precursors of choice are trimethyl aluminum, TMA, and water. During alumina ALD a pulse of TMA is introduced into the reactor resulting in a surface comprised of aluminum atoms followed by a water pulse that provides the oxygen atoms needed for exact alumina stoichiometry. During nominal operations the precursor gases are pulsed in from the same direction. In comparing size, TMA is a much bigger molecule than water due to the ionic radii of aluminum and the surrounding methyl groups. This increase in size, results in TMA having a much smaller diffusivity than water. It is this discrepancy in diffusivity that will be used to develop the bow tie or sharp whisker point type geometries. Instead of exposing one end of the pores to both precursor gases the gases will be split where one end of the pore is exposed to TMA while the other end is exposed to water. The foundation for this mechanism with resulting geometry was developed into a comprehensive model and published by the PI for his doctoral dissertation.

The development plan for this work in investigating ALD coated nanopores involves:

1. The modification of the existing reactor.

2. Procurement of the precursors and off the shelf nanoporous substrates.

3. Utilizing model results to capture the physical parameters for the reactor: temperature, pressure and precursor exposure rates.

4. Visualizing the geometries using TEM and SEM.

Anticipated Benefits

N/A

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Innovation Fund: GSFC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Peter M Hughes

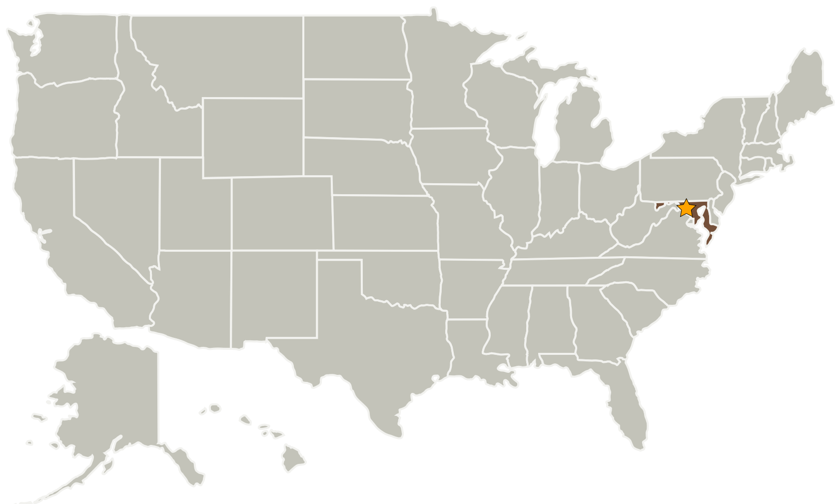
Project Manager:

Michael J Viens

Principal Investigator:

Vivek H Dwivedi

Primary U.S. Work Locations and Key Partners



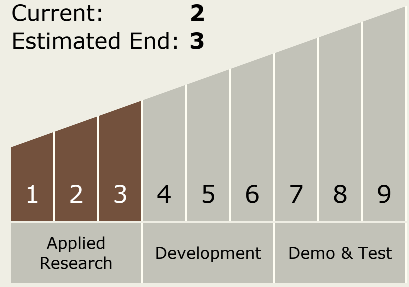
Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Co-Funding Partners	Type	Location
University of Maryland-College Park(UMCP)	Academia	College Park, Maryland

Primary U.S. Work Locations
Maryland

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **3**

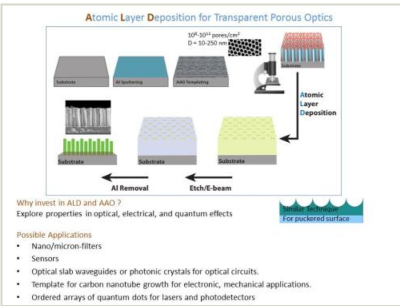


Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.2 Thermal Control Components and Systems
    └ TX14.2.2 Heat Transport

Images



Nanotubes formed by ALD
Method to create nanotubes, nanocones using ALD
(https://techport.nasa.gov/image/4177)

Links

GSC-17302-1
(https://ntts.arc.nasa.gov/app/)

GSC-17303-1
(https://ntts.arc.nasa.gov/app/)

GSC-17304-1
(https://ntts.arc.nasa.gov/app/)

Project Website:

http://aetd.gsfc.nasa.gov